Mathematical justification on the choice of explosive material to rupture strong rocks of complex structure

A.K. Ishchenko

PhD in Technical Sciences, Associate professor
National Mining University
Dnipro, Ukraine

S.A. Us

PhD in Physical and Mathematical Sciences, professor
National Mining University
Dnipro, Ukraine

A.V. Solovev

Bachelor, system analyst
National Mining University
Dnipro, Ukraine

K.S. Ishchenko

PhD in Technical Sciences, Senior Research Scientist
N.S. Polyakov Institute of Geotechnical Mechanics
National Academy of Sciences of Ukraine

Abstract
This work outlines the relevance, the purpose, the problem, the methodology and the results of research on explosive materials applied for rupture of strong rocks.
The purpose of this paper is to justify mathematically the choice of the type of explosive materials (hereinafter referred to as EM) with taking into account many criteria for this kind of practice. In the course of the current research, the selection of the alternative variants of the EM type for the rupture of strong rocks of a complex structure has been carried out. Our choice and the justification are based on many criteria (technological, economical, social and other indicators). The priorities for a systematic approach to the problem solution have been defined, namely: not only the benefits have been taken into account, but also the costs associated with the use of an explosive material. Factors characterizing costs when using charges from different types of EM have also been considered.
The solution of the problem has been carried out with the use of the hierarchy analysis method, which makes it possible to incorporate both quantitave, and qualitative criteria as well as to make judgement as to their significance for the choice of EM type, and also to check the consistency of expert opinions that are regarded in solving the problem. Based on the results of the problem solution, a vector of priorities has been obtained for each of the hierarchs, which allows us to justify the choice of the type of EM.
Key words: EXPLOSIVE MATERIALS, HEAT OF EXPLOSION, BOREHOLE CHARGE, NEWLY FORMED SURFACE, MATHEMATICAL SIMULATION, HIERARCHY ANALYSIS METHOD

Urgency of the research

Despite the development of new rupture technologies based on non-traditional approaches (thermal destruction, the effect of high energy particle flows, etc.), the explosion remains an effective method that is widely used in resource-saving and safe techniques for processing rock from underground mining. These methods are based on a deep study of the rupture mechanism of a strong polymineral environment of a complex structure and regard the connection between the gas and the dynamic effect to have on the energy of the explosion. From this standpoint, it follows that the mining effectiveness with the energy of explosion for uranium deposits and the completeness of their extraction from the rock massif should not affect the violations, which take place with the integrity of the region's ecosystem. This is explained by the fact that mining enterprises function under conditions of direct contact with industrial zones, residences, natural objects, water and agricultural lands and bear the negative impact on them [1-4].

The efficiency of the mine under these conditions can be increased by solving a number of tasks, including improving the organization of both labour and the safety of blasting operations, the quality of rock breaks, taking into account the anisotropy of the massif with simultaneous improvement on the parameters of drilling and blasting works, that are implemented in new methods of explosive rupture.

As we know, the problem solution on rocks rupture by the energy of explosion is on the margin of various sciences: geomechanics, physics of explosion, and mechanics of continuous media. At present, it draws the attention of researchers to its fundamental and practical significance. The studies in this direction made it possible to obtain new results with the explosive rupture mechanism of solid media of a complex structure, and made it possible to improve the existing methods for rock crushing control [5].

Among the tasks that arise in the organization of drilling and blasting operations, the problem of choice among explosives or explosive materials is becoming important. This task proves to be rather complicated, since the decision making on it requires considering a several criteria and requirements that include the quantitative and the qualitative indicators, which are not always correlate with each other.

The purpose of this research is to justify mathematically the choice of EM type taking into account the criteria stated above.

The problem to claim

Suppose we have several alternative variants of the EM type, which can be used to rupture hard rocks of a complex structure. It is necessary to make a rational choice of the explosives based on many criteria, which include technological, economical, social and other indicators. In addition, a systematic approach to the solution of the problem requires taking into account not only the benefits, but also the costs associated with the use of an explosive substance.

Materials and research results

Four types of EM have been studied, namely PETN (also known as PENT, PENTA, TEN), Ammonal, Grammonite 79/21, Anemix 80. The detonation characteristics of explosives, which were selected as criteria for expert evaluation in the rupture of rocks of different structures, were obtained during testing of laboratory experiments [8, 9], and from the earlier publications [6, 7].

The choice of EM type was assessed by the most significant indicators, which characterize the priority benefits of explosives application, namely they are:

- the optimal diameter of an average piece to estimate the results of the rupture of a solid environment by explosion;
- the area of the newly formed surface;
- degree of crushing;
- explosive materials saving;
- indicator of explosion heat;
- the amount of energy needed to form a unit of a new surface.

Moreover, in the research, we also have considered the factors related to the costs for the use of various EM charges [9]:

- the cost of EM;
- hazards to the environment;
- the costs of preparatory work for the drilling and blasting;
- extra expendures for complex measures of individual safety of working personnel.

Furthermore, in order to solve the stated problem, the hierarchy analysis method has been chosen. This method allows us to embrace the quantitative and the qualitative criteria, employ their significance in the choice, and also to check the consistency in the opinions of experts, which are also regarded in solving the problem [10]. Two types of hierarchies have been constructed in the course of the problem solution. The first one describes the benefits, and the second hierarchy estimates the expenditures for a certain EM type. Thus, the scheme of the hierarchy of benefits can be illustrated as shown in Fig. 1.

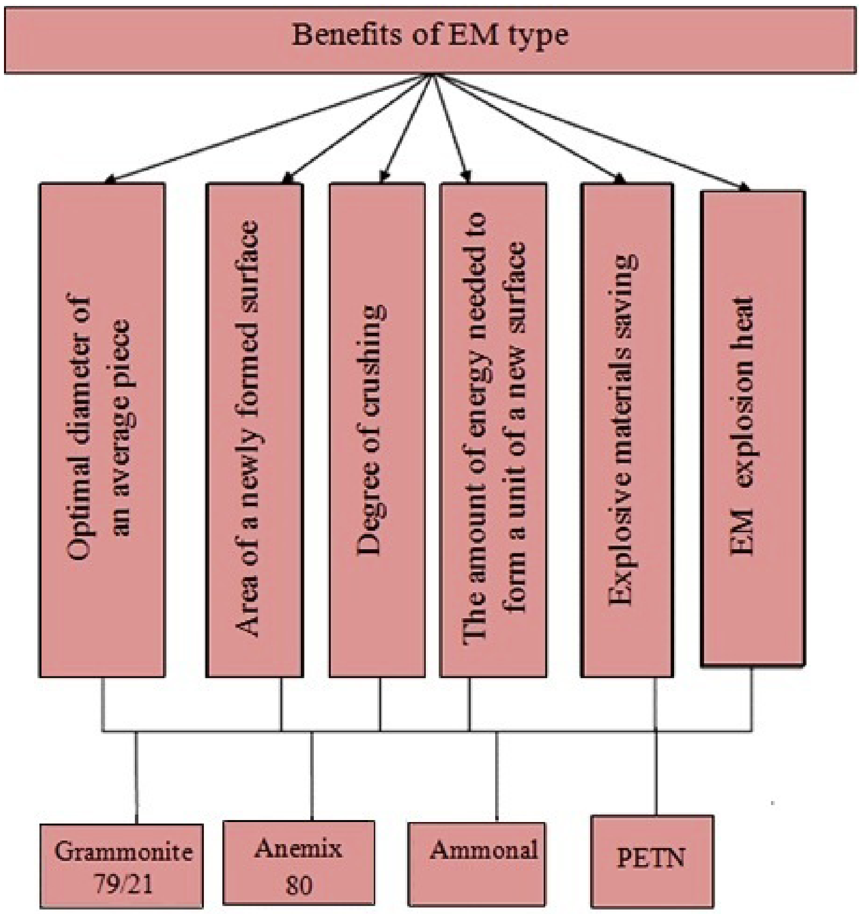

Figure 1. Hierarchy of benefits in solving the problem of the explosive material choice

Eventually, the result of the problem solution is in the vector of priorities, which enables us have the grounded choice of EM type. The outlined priorities for each of the hierarchies are shown in Table 1. With the both results taken into account, two types of contraction have also been considered.

Table 1. Results of solving the problem by two hierarchies

EM type	PETN	Grammonite 79/21	Anemix 80	Ammonal
Benefits	0.348	0.264	0.114	0.274
Costs	0.365	0.261	0.112	0.262
Benefits /costs	0.955	1.014	1.008	1.047
Benefits-costs	-0.017	0.003	0.001	0.012

Analyzing the results of the problem solution, we have found out that the benefits of the PETN application are of the highest priority, since this substance has a high ability to rupture a solid medium due to the high heat and temperature of the explosion, but it is also the most expensive method. Thus, Grammonite and Ammonal have rather close values of priorities with respect to the benefits and the costs. This indicates that they have very similar detonation characteristics and the composition of the explosive. Currently, Anemix is the most preferable in terms of costs and less harmful to the environment as it has the lowest value of harmful gases emission, zero oxygen balance, the lowest price and its use does not require extra expenses.

Therefore, if the choice is made only with relation to the benefits – PETN can be treated as the most preferable explosive, although the cost of Anemix draws the preferences to its side. In a joint consideration of the problem solution results, it becomes clear that either Grammonite or Ammonal should be considered as preferred explosives.

The use of the hierarchy analysis method allows a balanced approach to the selection and justification of the EM type, which is of great importance in the design of rational parameters of drilling and blasting operations for the rupture of solid rock of a complex structure in mines.

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